



MULTIFUNCTIONAL TOXIN DECONTAMINATION COATINGS

for Sustained Protection of People and the Environment

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CURRENT TECHNOLOGIES AND LIMITATIONS

Physical Barrier Protection

- Selective Adsorption
 - Activated charcoal - HEPA system
- Impermeable Polymer Barriers

Drawbacks:

- Contaminated barriers are hazardous and cause disposal problem
- Impermeable barriers cause heat and perspiration



Active Protection

Chemical Catalysis Approach

- Oxidants (TiO2)
- Metal chelators
- Engineered catalysts

Drawbacks: Catalysts destroy filter; Very slow, Not efficient

Enzymatic Catalysis Approach

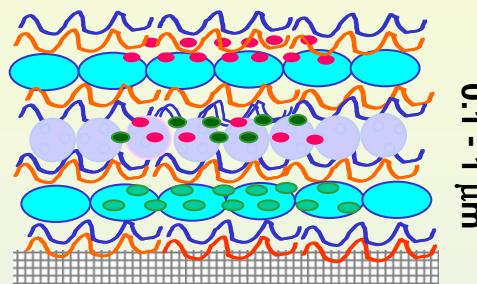
- Free enzyme in solution
- Cross-linked to a substrate

Drawbacks: - Limited stability in working environment
- Loss of activity during processing

Our Approach Removes Most of these Limitations
and
Provides Additional Capabilities

OUR APPROACH

Enzyme Based Multifunctional Coatings

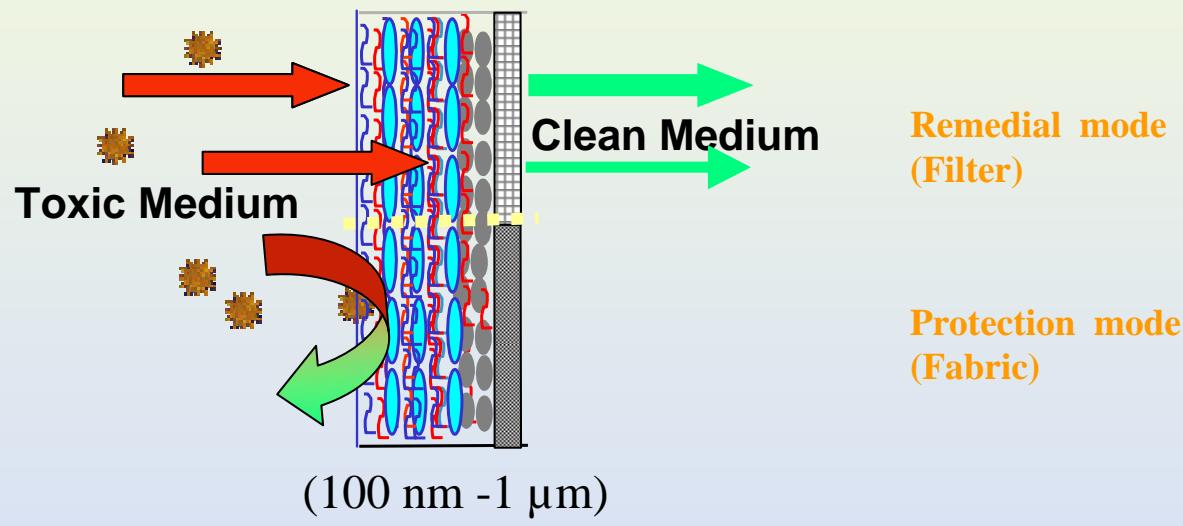


Incorporates advantages of enzymes by embedding them in multilayers, which leads to

- Stability
- Sustained catalytic efficiency
- Multifunctional capability
- Light weight
- Cost effective
- Hazmat-free
- Reusable

MULTIFUNCTIONAL SELF-CLEANING FILTERS

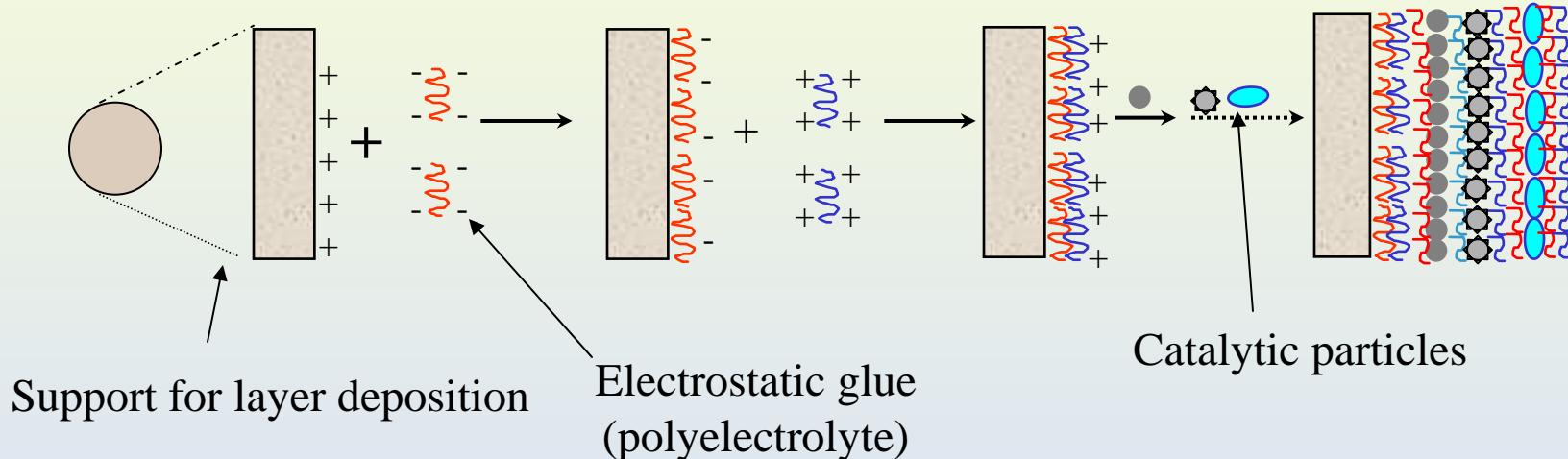
Protect personnel and the environment from chemical and biological agents, and toxins produced during their degradation.



Single System \Rightarrow **Multi-protection**

MULTIFUNCTIONAL MULTILAYER FABRICATION

Layers are assembled by *complementary association of macromolecules* on surfaces varying in size, shape and texture



Fabrication Involves Water based Chemistry and Proven Film Deposition Techniques

- Dipping
- Spraying
- Spin coating

Automation Makes the Film Fabrication Cost Effective

CHEMICAL AGENT PASSIVATION: Components and Scheme

CATALYSTS

Organophosphorous Hydrolase (1) OPH

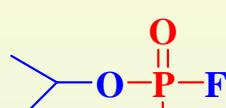
Organophosphoric acid anhydrolase (1) OPAA

SUBSTRATES

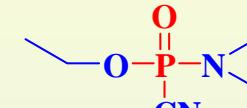
Cloth: Cotton, Glass

Beads: Polycyclodextrins

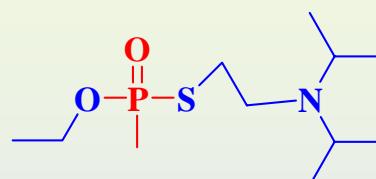
NERVE AGENTS/ PESTIIDES



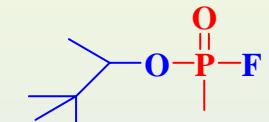
Sarin (GB)



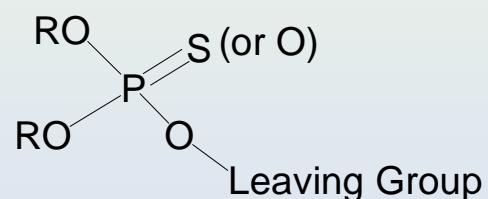
Tabun (GA)



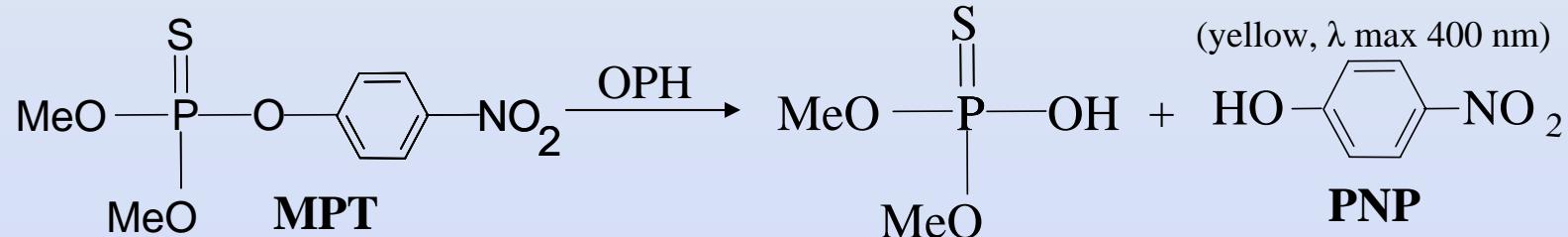
VX



Soman (GD)



Methyl parathion (MPT) hydrolysis for activity assays:



NOVEL CAPABILITIES DEMONSTRATED

- Stability of Enzymes in Multilayers
- Stability of Multilayers in Working Environment
- Control over Enzyme Loading in Multilayers
- Enzyme Performance on Various Supports
- Enzyme Activity Independent of Solvent, pH, and Temperature

UTILITY OF MULTIFUNCTIONAL COATINGS

1. Environmental Protection:

Support - Beads

- Water filters
- Air filters (● Small rooms; ● masks)

2. Individual Protection:

Support - Cloth

- Full body aprons
- Easy-breath masks

3. Surface Protection:

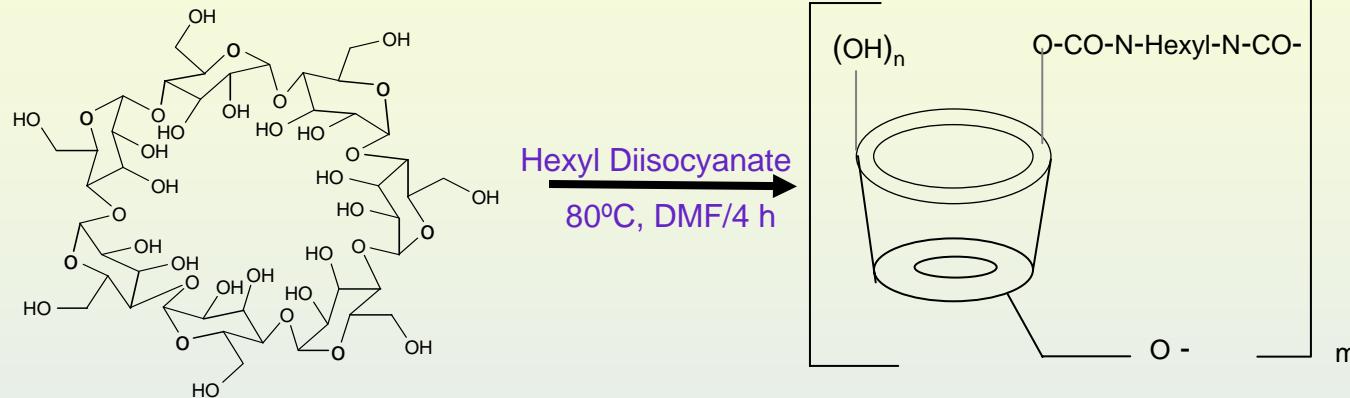
- Appliqué
- Paper Towel/Wipes

The application dictates the nature of the support

ENVIRONMENTAL PROTECTION: Poly- β -Cyclodextrin

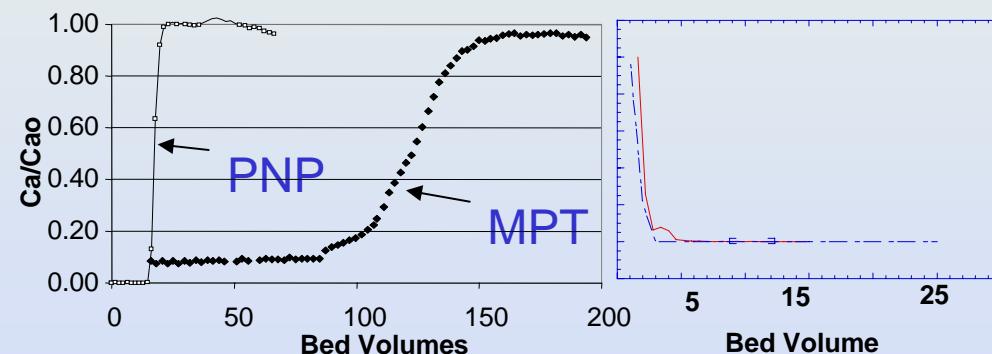
Substrate for Multilayer Assemblies

System:



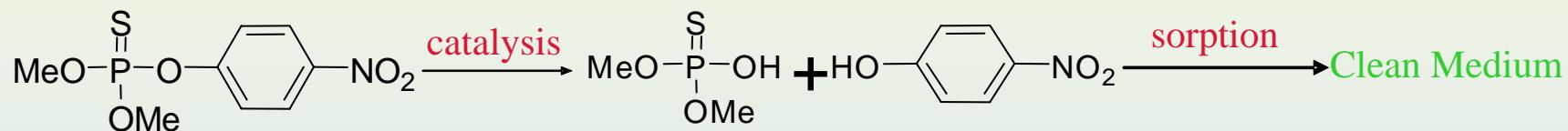
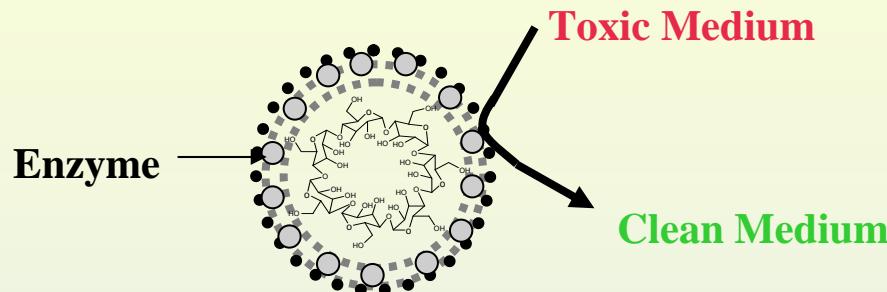
Features

- surface area: $10.2 \text{ m}^2/\text{g}$
- A total pore volume : $0.06 \text{ cm}^3/\text{g}$
- Insoluble in most organic solvents
- Inert to acidic, basic media and
- 4-Times lighter than glass beads
- Capture toxins such as pNP and MPT



ENZYME COATED POLY- β -CYCLODEXTRIN BEADS

Sequence: PCD-BPEIH2O(pH 8.6)-OPHBTP(pH 8.6)-BPEIBTP(pH 8.6)



Catalytic Activity of OPH-PCD

Environment

Ambient condition (23 °C)

Low temperature (4 °C)

Methanol-2h

Acetone 2h

Salt Stress-NaCl (2M)-2 h

Tap water for 24 h

Water (pH 6.6)

Initial velocity (V₀)

1.9×10^{-7} M/sec

1.4×10^{-7} M/sec

6.4×10^{-9} M/sec

1.8×10^{-8} M/sec

9.6×10^{-9} M/sec

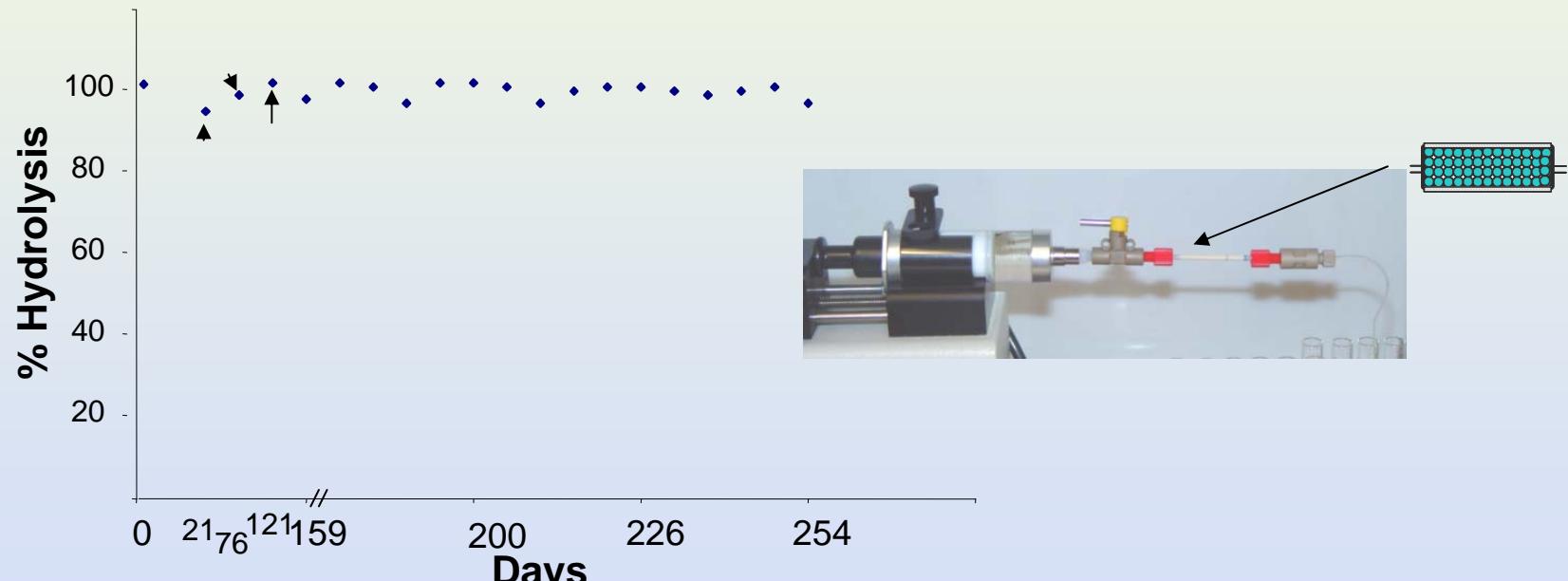
1.1×10^{-7} M/sec

3.6×10^{-7} M/sec

FILTERS FOR ENVIRONMENTAL PROTECTION: Results

Self-cleaning Filter Using OPH Coated Polycyclodextrin Beads:

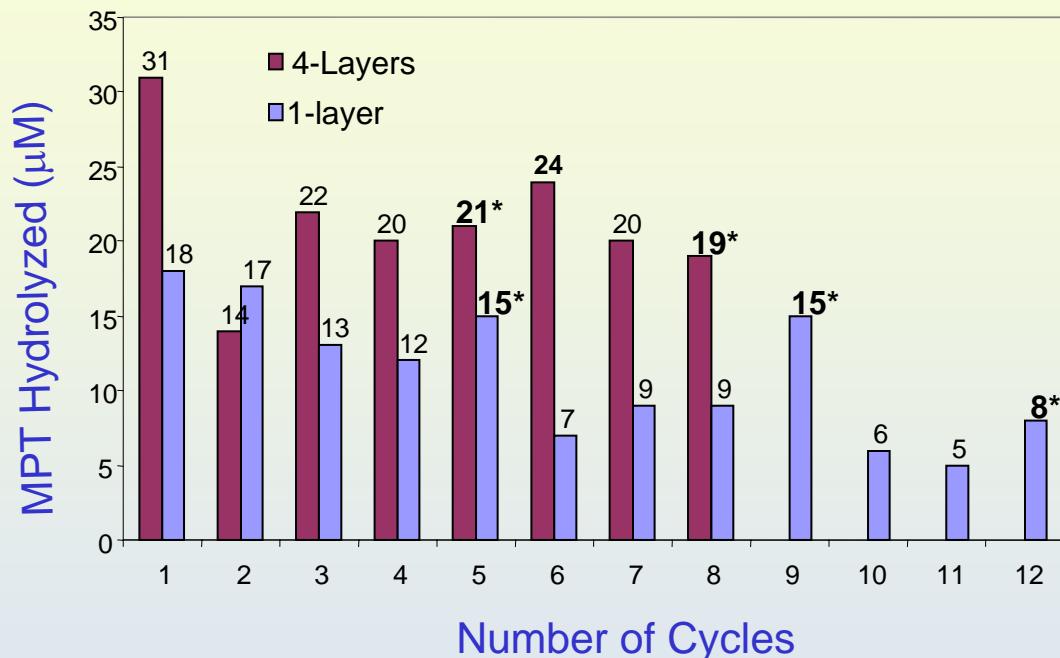
- Degrades 99+, 100 μ M MPT at a flow rate equaling 1.9 min column resident time
- 32 mg MPT was degraded by 23 mg OPH/PCD beads \equiv *1 g Enzyme degraded 177 g Pesticide MPT*
- Sustained hydrolytic activity for 250 Days demonstrated



US Patent Pending (Applications # 10/750,637; December 23.2003)

SELF-CLEANING FIBERGLASS: Results

Sequence: Cloth-**BPEI(H₂O)-OPH/BTP-BPEI/BTP-(PSS-BPEI(H₂O)-OPH/BTP-BPEI/BTP)₃**



MPT Hydrolysis capacity

56mg /g cloth (4-Layers in 2-week)

44 mg /g cloth (1-Layer in 3-weeks)

* Activity measured after storing the cloth at 4 °C for the weekend

Results Demonstrated:

- Retention of enzyme activity
- Resistance to washing cycles
- Reusability

OPH IN MULTILAYERS ON KNITTED FABRIC



Both, cotton string coated with OPH (1-Layer) and the cloth knitted from the OPH-coated string showed identical activity: ~80% MPT (2mL, 100 μ M) was hydrolyzed within 5 minutes.

Mechanical Stability Demonstrated

Cost to Cover 1 Enzyme layer on 100 m² Fabric \leq \$ 5.00

US Patent Pending (Applications # 10/849,621, May 20, 2004).

CONCLUSIONS

Proof-of-Principle for the Protection of Individuals and the Environment from chemical agents is established

- * Light weight, reusable fabrics with mechanically stable coatings
- * Filters for decontamination of water supplies
- * Sustained catalytic activity independent of solvent, buffer or temperature

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